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THE INSTITUTE FOR FLIGHT MECHANICS, BRAUNSCHWEIG (081) AND STUTTGART (027)

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D. C. 20546 DECEMBER 1973

THE INSTITUTE FOR FLIGHT MECHANICS, BRAUNSCHWEIG (081) AND STUTTGART (027) * **

Author Unknown

STRUCTURE OF THE INSTITUTE

/97***

Mathematical Techniques
Director: Dr.-Ing. E. A. Bockemüller

Rescue and Recovery Systems
Director: Dipl.-Ing. H. D. Melzig

Flight Mechanics of Aircraft Vehicles
Director: Dr.-Ing. K. Wilhelm

System Analysis
Director: Mrs. Dr.rer.nat. E. Schwartz

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* Director: Dr.-Ing. Peter Hamel, S.M.
Alternate Institute Director (Commission): Dipl.-Lng. Hans-Dietrich Melzig

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Telex: 9 52 800 (dfvlr)

** Numbers in parenthesis: 3 digits, for example (012) = characteristic number for the institute or the installation; 4 digits, for example (0123) = topic number of the research plan for the corresponding installation; 7 digits, for example (012 0123) = topic number in conjunction with a certain research installation. Numbers in brackets, for example [12] = reference to the corresponding position in the literature list.

*** Numbers in the margin indicate pagination of original foreign text.

Flight Test Technique

Director: Dipl.-Ing. H. Meyer

Helicopter Systems

(Institute for Helicopter Aircraft up to July 31, 1972)
Director: Prof. Dr.-Ing.habil. W. Just up to July 31, 1972)
Director: Dipl.-Ing. H. Georgi (Commission assignment after August 1, 1972.

I. GENERAL REMARKS

1. Number of employees on December 31, 1972

	(081)	(027)
Hired scientific collaborators	40	11
Free lance scientific collaborators	1	-
Engineers with degrees and scientific-technical assistance	26	3
Technical specialists	16	5
Office help	7	1
On payroll	6	-
Total	96	20

Prof. Dr.Ing. G. Brüning, professor for flight mechanics at the Technical University of Braunschweig, is an advisor for the Institute.

2. Special activities

2.1 Teaching activity

F. Hammelrath, E. Schwarz and G. Wulff were invited by the Academy for Armament Management and Armament Technology to give 20 hours of lectures on advanced technical service and lectures on the higher technical service.

Because of the response to the courses given in previous years, the Systems Analysis Division was requested by the Carl Cranz Association to carry out additional courses regarding evaluation techniques. C. Doukas, F. Hammelrath, E. Schwarz and G. Wulff collaborated in this (49 lecture hours).

For the first time and with the collaboration of the Technical High School, Darmstadt, the Aircraft Flight Mechanics Division gave a Carl Cranz course on "Flight Property Requirements for V/STOL Aircraft". This course discussed the directives which have been created over the last few years (AGARD-Rep. No. 577 and MIL-F-83 300). It discussed the requirements and made a critical comparison. D. Hanke, G. Rosenau and K. Wilhelm participated in the lectures.

Since 1965 and because of a suggestion of co-workers, five semester courses for the development of mathematical-technical assistance have been given for persons from industry, research institutes and advance school institutes. In April, the fourth course given by the Research Center Braunschweig of the DFVLR started. In September the third course was concluded with a test given by the industry and business association. F. Hammelrath, F. Henschel, K. Pfeifer, E. Plaetschke and G. Wulff from the Flight Mechanics Institute are lecturers.

2.2 Collaboration in committees and other panels

E. A. Bockemüller: DGLR Committee 4.1 "Flight performances and trajectories" (alternate Obmann);

P. Hamel: DGLR Committee 4.2 "Flight Properties" (alternate Obmann). Member of the Advisory Committee of the Central Organization for Aerodynamics and Space Flight Documentation and Information (ZLDI). Member of the Working Group "Directives" of the DFVLR. Member of the committee "Short and Vertical Takeoff Aircraft" of the Aerodynamic Advisory Committee. Member of the AGARD Flight Mechanics Panel. Representative of the Special Committee 2, "Flight Mechanics, Flight Control" of the DFVLR (after October 13, 1972). Member of the Working Group, "Noise Research" of the DFVLR;

F. Hammelrath: VDI/VDE Committee "Reliability and Quality Control". Coordination Committee "Systems Technology" of the Working Group for large research projects (AGF);

D. Hanke: DGLR Special Committee 4.2 "Flight Properties";

H. Herb: DGLR Research Group 12, "History of Aviation and Space Flight" (alternate Obmann);

W. Just: DGLR Special Committee 2a, "Rotary Wing Aircraft" (alternate Obmann);

R. Koehler: DGLR Research Committee 4.2, "Flight Properties". DGLR Special Committee 4.6, "Flight Test Technology";

M. Marchand: DGLR Special Committee 4.2, "Flight Properties" DGLR Special Committee 4.6, "Flight Test Technology";

H. D. Melzig: AGARD Flight Mechanics Working Group "Escape Measures for Combat Helicopter Crews".

E. Mewes: DGLR Special Committee 4.7, "Concept Determinations (simultaneously Working Committee 801 for the Aviation Standards Office; Obmann up to July, 1972). Sub-committee ISO/TC 20/SC 3 "Terms and Symbols in Flight Dynamics";

G. Rosenau: DGLR Special Committee 4.7, "Concept Determinations (simultaneously Working Committee 801 for the Aviation Standards Office; Obmann up to August, 1972). Sub-committee ISO/TC 20/SC 3 "Terms and Symbols in Flight Dynamics";

E. Schwarz: DGLR Specialist Group 1, "Systems Technology", Specialist Committees 1.1, "Future Research and Systems Planning" and 1.2 "Project Management";

K. Wilhelm: DGLR Specialist Committee 4,2 "Flight Properties" DGON Commission for Aviation.

2.3 Advisors to public officials and project organization.

H. Bestek and R. Jamka participated in the Deicing Experiments with the Helicopter BO 105 at the National Research Council in Ottawa, Canada.

H. Georgi, B. Gmelin, A. Kussmann, G. Schilling were advisors for the evaluation of Research Projects of the ZTL Program in the area of Rotary Wing Aircraft for the German Military Authorities (BMVg).

F. Hammelrath held a lecture at the meeting of the NATO Study Group AC 243 on November 20/21, 1972 in St. Louis.

P. Hamel participated in the MRCA Review meetings on October 10/13, 1972 and November 23, 1972 at the request of the German Military Ministry.

P. Hamel collaborated in the development of a joint test and experimental program for a future V/STOL Transport System using the Do 31-E 3, at the request of the DFVLR and the Firm Dornier.

R. Koehler, M. Marchand, G. Rosenau and K. Wilhelm were advisors in the evaluation of the research project ZTL Program in the area of Area Aircraft, at the request of the German Military Department.

B. Krag worked at the Associated Aircraft Factories VFW Fokker in Bremen from June through August, 1972. He was assigned to the VFW Fokker in the Structural Dynamics Division in order to carry out urgent assignments in connection with the flutter safety certification for the aircraft prototype VFW 614.

H. D. Melzig, in conjunction with W. Beduhn, G. Braun, K.-F.Doherr, P. Hoenen, P. Hundemer, R. Koch, D. Münscher, D. Schmerwitz, U. Schmidt, W. Schmidt and J. Wirth carried out a meeting on the topic "Problems, Results and Development Tendencies in the Area of Parachutes and Ejection Seats" on April 26/27, 1972. He is a lecturer from the Division of Recovery and Rescue Assistance". The German Military Department and its subgroups were invited to this meeting.

E. Schwarz is a member of Commission I of the NATO Study Group AC 243; she was a lecturer at three meetings of the group (August 30/31, 1972 in Copenhagen, November 14/16, 1972, in Rome, and November 20/21, 1972 in St. Louis. /99

2.4 Scientific connections with domestic and foreign organizations

K.-F. Doherr gave a lecture on the rescue system projects of the Institute during the second DFVLR Journalist Seminar on

October 16, 1972 at the Braunschweig Research Center.

K.-F. Doherr participated in high altitude rocket experiments from September 17 to October 3, 1972 at Wallops Island, USA, as a specialist in the area of Rescue Assistance. These were carried out from the mobile rocket base of the DFVLR.

P. Hamel gave a lecture on "Noise Reducing Approach Method" during the second DFVLR Journalist Seminar.

P. Hamel gave a lecture on the topic, "Methods for Aircraft State and Parameter Identification", on October 26, 1972 at the Working Group Meeting of the AGARD Flight Mechanics Panel.

D. Hanke was a guest lecturer of MBB-UH on September 13, 1972 on the topic of Aircraft with Variable Flight Properties.

There were discussions between R. Jamka and G. Kempe and the representatives of the firms MBB-UD, Dornier and VFW for the purpose of building a research rotor for wind tunnel measurements.

T. Kallfass and K. Czarnowski carried out flight measurements in order to determine the magnitude and frequency of load multiples which occurred during flight. This was done in conjunction with the helicopter squadron of the Baden-Württemberg State Police.

G. Rosenau was a guest scientist between March and June, 1972 in the "Structural Strength" group of the ONERA in Chatillon (France). There he participated in work on active gust reduction (081 0144). During the French-German Specialists Talk in St. Louis on November 6/7, 1972 and in conjunction with this visit, an agreement was made for collaboration between the ONERA in the area of gust reduction.

There were close relationships with the Federal Aviation Administration (FAA) regarding flight mechanical investigations for steep, noise-reducing landing approaches.

Talks were held with the test group 61 of the German Army in Manching regarding the possibility for close collaboration in the area of flight test technology and flight testing.

There was a continuous exchange of results in the area of subsonic parachutes with the Air Force Flight Development Center of the U. S. Air Force. This was done on the basis of a data exchange agreement.

2.5 Visits

April 12, 1972: AGARD Flight Mechanics Panel. Visit during this "stability and control" meeting.

Visit of the test installations in two research aircraft of the type DO 27. Explanation of the Mobile Telemetry Ground Station, dropping of a personnel parachute system with an instrumented dummy for low drop heights using the DO 27 from a flight altitude of 30 m. Test experiment for systems identification. Installation of a noise generator in the elevator of the DO 27, flight altitude 500 m. Exhibit of projectiles, parachutes, etc. Summary drawings of the variable flight property aircraft HFB 320. Summaries of the determination of the coefficients. Data processing station, on line demonstration for determining the coefficients using a hybrid computer.

May 29, 1972 and November 16, 1972: Visits by R. Berndt, U. S. Air Force, Dayton, Ohio, USA.

Talks regarding the data exchange agreement on the determination of scale influences for parachutes. Exchange of results, adjustment of the common computer programs for data storage and recall, determination of further test programs.

Dr. Juan J. Martinez from the Escuela Tecnica Superior de Ingenieros Aeronauticos, Technical University of Madrid, professor for flight mechanics, visited the Flight Mechanic Institute on August 16, 1972. He gave a lecture on "Aerodynamic Interference between Surfaces Oscillating in Subsonic Flow. Calculation of the Response of the System to a Stochastic Input." He also discussed the structure of a modern lecture on flight mechanics.

3. Promotions, personal data

T. Kallfass was given the engineering doctorate degree based on his thesis "The Realization of Prescribed Stability and Controllability Flight Properties of a Helicopter using Control System Devices" at the University of Stuttgart.

E. Plaetschke obtained a doctor's degree at the Technical University of Braunschweig with his thesis, "Investigations on the Non-Steady Method for Calculating the Frictionless Flow around Blunt Bodies in Supersonic Flow".

G. Wulff was granted a scholarship from the French Government by Professor R. Fortet for a six week stay in Paris at the Chaire de Calcul des Probabilités et Physique Mathématique.

P. Hoenen obtained a Class III Flying Instructor License from the West German Aviation Ministry.

H.-J. Klewe obtained an instrument flying license.

P. Redelhammer, H. Reetz and H. Pietsch passed the examination for mathematical-technical assistants.

4. Test installation and equipment at the institute

Electrically controlled servo systems for landing flaps and engines, installed in the aircraft HFB 320-S1 with variable flight properties.

Elastic flight model for wind tunnel stimulations.

Onboard measurement installation for test flights based on a building block principle, used as equipment for research aircraft.

Mobile research rotor installation for wind tunnel investigations (under construction).

Mobile telemetry and telecommand ground station for flight tests with research aircraft and drop experiments with instrumented projectiles.

High frequency normal film camera up to 300 frames/second.

Semi-automatic evaluation installation for cinetheodolite films, 35 mm films and 16 mm films.

Instrumented projectile for investigating rescue and recovery systems by means of a ten-channel telemetry onboard station. Weight classes between 6 - 400 kg.

Horizontal compressed air installation for instrumented projectiles with a weight of 6 kg and exit velocities up to 150 m/sec.

II. SCIENTIFIC WORK

1. Mathematical methods
Dr.-Ing. E. A. Bockemüller

1.1 General remarks

The main papers on topics emphasized by the DFVLR in the area of space flight mechanics have been concluded and published.

Of these, we would like to mention the investigations by Dr.-Ing. E. Plaetschke on a numerical technique for calculating hypersonic flow around blunt bodies, which has been concluded. A number of sample calculations which are applicable for the reentry of bodies into the atmosphere will be published in a subsequent research report [13].

Regularizing transformations in the calculation of the launching of satellites were used by Dipl.-Math. F. Henschel. There is a symmetrization and smoothing of the directional field of the perturbation equations. By applying the theory of linear differential equations with periodic coefficients, it is possible to solve the perturbation equations with a method that saves calculation time. From the practical point of view, it /100
is especially important that launch trajectories can be calculated which start from eccentric parking orbits. For example, we calculated the spiral ascent trajectory of a satellite from a parking orbit near the earth into a geostationary trajectory for a small horizontal thrust [6].

K.-H. Well, Ph.D. was able to successfully include his studies at the Rice University at Houston, Texas (USA) during the report year. He published three additional papers in the area of numerical optimization methods [17, 18, 19]. Because of a reorganization on October 1, 1972, he changed to the Institute of Flight System Dynamics of the DFVLR in Oberpfaffenhofen.

Dipl.-Ing. H. Sommer published a final paper on space flight trajectories with tangential thrust, in the form of a research report [16]. In this paper, transitions were investigated which are made up of two powered phases and one free flight phase. The powered phases are calculated by steps using analytic integration. In this way, a high degree of accuracy is obtained with a small computation effort. The example of a transition from a 200 km circular into a 24-hour trajectory with an electrical propulsion system shows that the final errors can remain sufficiently small even after the required 620 revolutions.

1.2 Noise-optimal flight trajectory profiles of V/S/CTOL aircraft (081 0142)

1.2.1 Noise-reducing takeoff trajectories

A review of the extensive noise yield calculations for straight takeoff trajectories carried out by Dipl.-Math. F. Henschel, Dr.-Ing. E. Plaetschke and Dipl.-Math. H.-K. Schulze showed that the application of optimization methods for the minimization of aircraft noise is promising. As a measure of the flight noise, we used an extension of the functional EPNL (effective perceived noise level) which is defined in the Federal Aviation Regulations, Vol. III, Part 36 (Noise Standards Aircraft Type Certification). This is because EPNL itself is not suitable as a target function in optimization methods. We considered piecewise straight takeoff trajectories. The discretisation connected with this made it

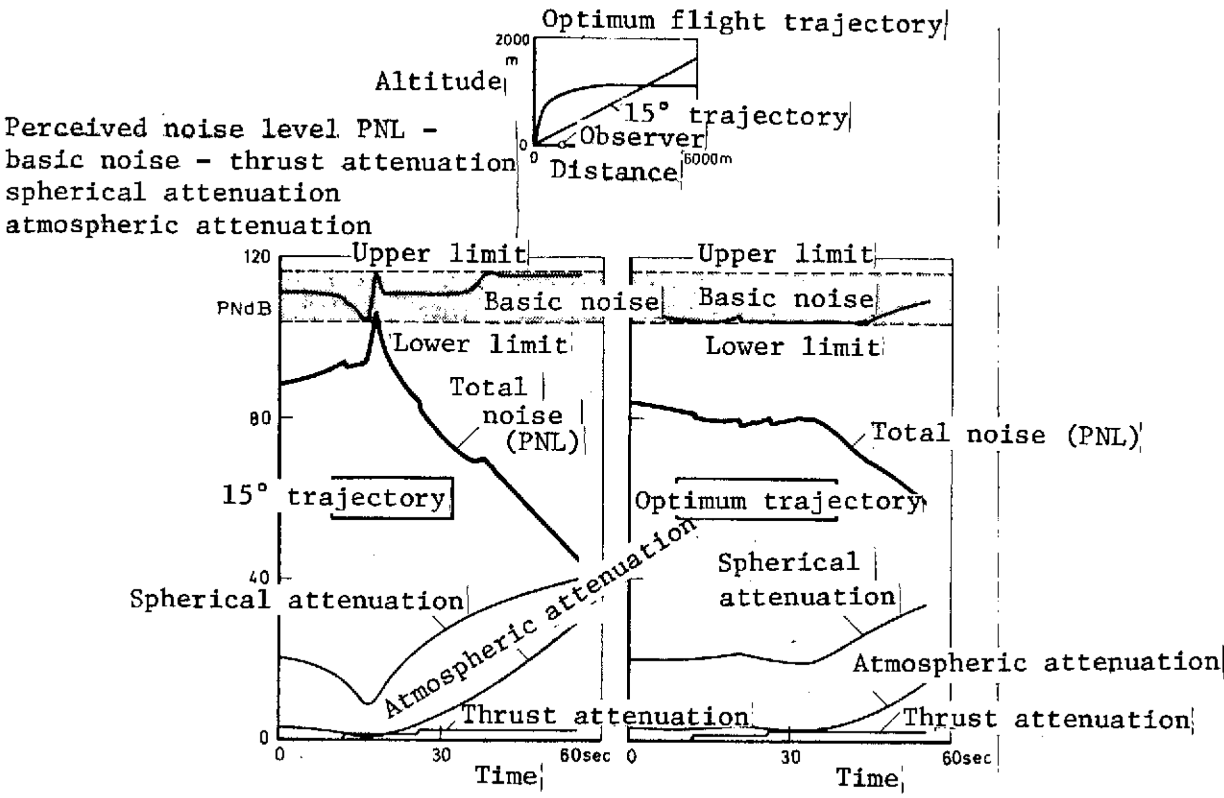

Figure 1. Variation of the perceived noise level PNL and the individual noise components for take-off of a VTOL aircraft for a 15° flight trajectory optimized with respect to noise. (From [52]).

possible to apply dynamic optimization methods (Bellman principle). We used a variation of this method which saves storage space and computation time and which was developed by Dipl.-Math. H.-K. Schulze.

The optimization was carried out for a VTOL aircraft with a set of engines which could be deflected and with a thrust/ weight ratio of $S_{max}/G = 1.26$. Figure 1 shows a variation of the perceived noise level PNL which is perceived by an observer at a distance of 1000 m as well as the variation of the various noise components for a 15° trajectory. It also shows the noise-optimal trajectory [52] for this observer.

Dr. K.-H. Well attempted to apply the methods described in [17, 18, 19] to noise-optimal flight trajectories. Because of the special features of the problem, and because of the complicated nature of the target function, no satisfactory convergence has been obtained up to the present. Additional investigations are necessary.

1.2.2 Steep landing approaches

Dr.-Ing. E. A. Bockemüller carried out parametric investigations of steep and noise-reducing landing approaches. This will provide important information for the flight test program of the institute using the research aircraft HFB 320-S1. Information is desired regarding possible pullout maneuvers using the three control variables: elevator, landing flap (direct lift control, see Section II.3.6 of this report) and thrust throttling. Since at the present time two-segment approach profiles are being prepared within the framework of the flight test program (0147), this program was especially interested in the transition arcs from a steep trajectory segment to a conventional 3-degree ILS flight trajectory profile. We also considered the influence /101
of the regulator rate limitations in the control organs as well as the reaction time of the pilot.

At the same time as the numerical procedure was being developed, Dr.-Ing. E. A. Bockemüller determined simple analytical relationships in the treatment of the equations of motion, which led to a generalization of the problem of determining optimal transition arcs [42].

Figure 2 shows the influence of the regulation rate limitation (switching time T) for the research aircraft HFB 320-S1 on the transition arc between a six-degree of freedom approach trajectory and a three-degree of freedom approach trajectory.

1.3 Aeroelastic influences on flight mechanics (081 0143)

1.3.1 Longitudinal motion

The mathematician W. Kleinschmidt established a computation procedure for determining the transition matrix for the longitudinal motion of elastic aircraft. He considered non-steady aerodynamic effects in the linearized equations of motion. The eigen oscillation modes and the lift weighting functions (circulation functions) can either be specified analytically or can be approximated using a sub-program if support points are specified. For example, using this method we calculated all transfer functions of the research aircraft HFB 320-S1 in connection with gust reduction problems (0144). Figure 3 shows the poles and zeros of the transfer functions in the complex plane considering the elasticity of the aircraft: wing bending due to elevator deflection (Case A), landing flap deflection (Case B), symmetric rudder deflection (Case C) and vertical gusts (Case D).

1.3.2. Side motion

Dipl.-Ing. B. Krag established a mathematical model for the side motion of elastic aircraft. The aerodynamic forces are calculated using the strip method. He used a quasi-steady as well as an unsteady aerodynamic force law. In the case of the unsteady aerodynamic force law, we used the "indicial function concept". The lift weighting function (circulation

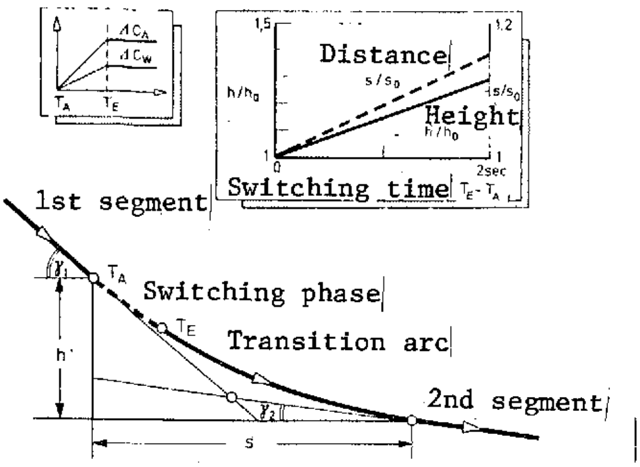

Figure 2. Influence of the regulation rate limitation or switching time of control variables on the pullout arc of broken approach trajectories (h_o = height and s_o = distance without regulation rate limitation). Sample calculation for the research aircraft HFB 320-S1 with lift control:
$\gamma_1 = -6°$; $\gamma_2 = -3°$; $V_1 = 87$ m/sec; $C_A = 0.056$; $C_W = 0.018$.
(from [42]).

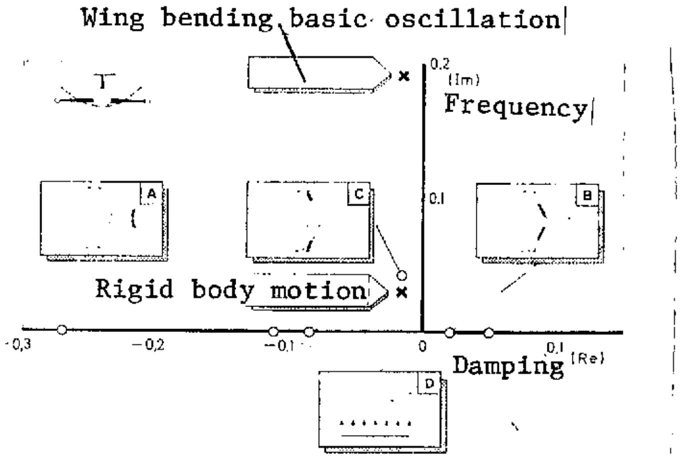

Figure 3. Pole (x) and zero (0) distribution of the wing bending basic oscillation transfer function of the research aircraft HFB 320-S1 for various inputs: A = elevator, B = landing flaps (lift control), C = symmetric rudder, D = vertical gust (From [58]).

function) was described using an approximation. We found that for lifting surfaces with a small aspect ratio, the calculations can be performed without a circulation function. When we recalculated the lift distribution using a rudder of the SAAB 105 carrying out harmonic oscillations, we found that there was good agreement with other calculation methods. In addition, we /102
investigated appropriate control systems which artificially damped elastic eigen oscillations and which reduced reactions of aircraft to gust disturbances. In order to determine the optimum controller loss, we developed an extended root locus method and

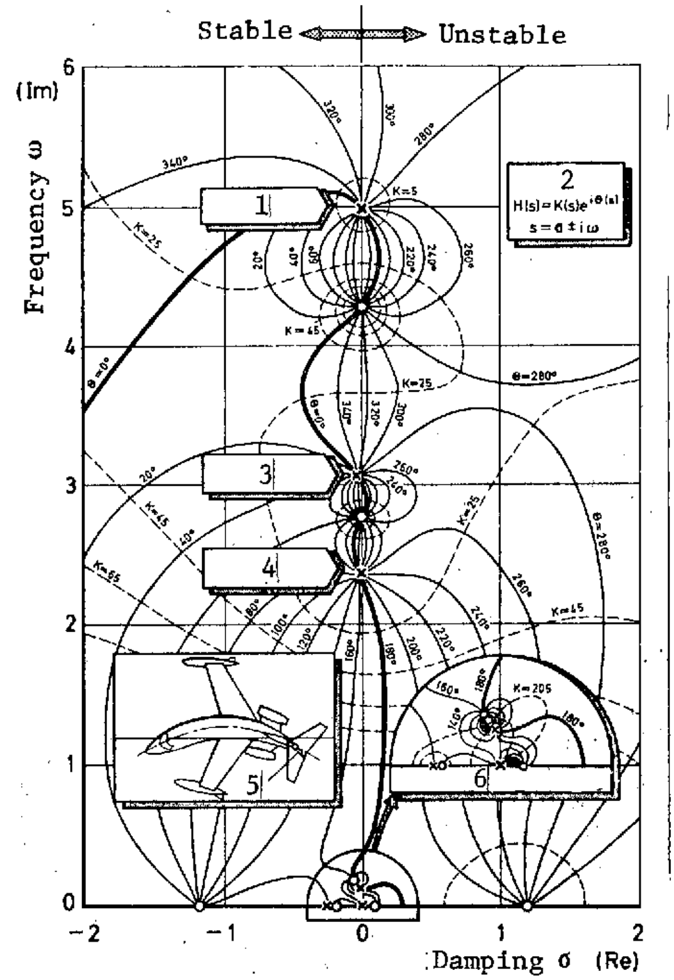

Figure 4. Extended root locus curve method for determining an optimum controller for the research aircraft HFB 320-S1 of the DFVLR.

1- fuselage bending, 2- controller structure, 3- side rudder torsion, 4- side rudder bending, 5- side rudder, 6- rigid body motion.

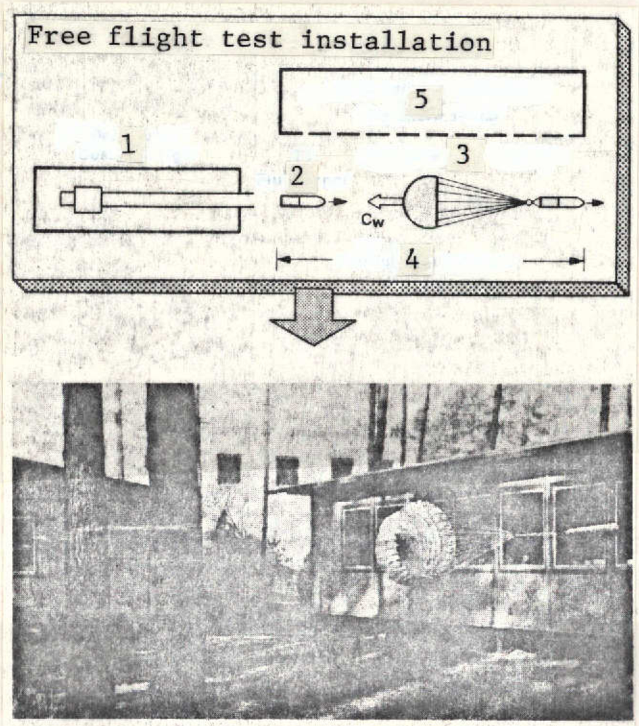

Figure 5. Free flight test installation for investigating the influences of models during parachute experiments, for investigating the stability of parachute-load systems and for investigation high velocity parachutes; (C_W - drag coefficient).

1- compressed air accelerator, 2- projectile, 3- test parachute, 4- free flight measurement distance, 5- electronic-optical data processing.

applied it to the aircraft HFB 320-S1 (Figure 4).

2. Recovery and rescue systems

Dipl.-Ing. H.-D. Melzig

2.1 General remarks

The division is divided into three working groups. One group primarily deals with rescue systems and associated partial problems, which are primarily specified by the Federal Defense Minister.

The second group works on problems in the area of recovery systems. These extend from the evaluation of commercially available systems up to new designs for special purposes. Numerous basic studies are required in this area, for example, investigations of scale influences as well as the stability of parachute-load systems. The tasks for this group primarily are specified by the Federal Ministry for Education and Science, as well as for research and technology.

The third group deals with the development and operation of the special measurement equipment and with the instrumented projectiles.

The research task described in the following was written in close collaboration among the three working groups.

2.2 Scale influences with parachutes (081 0113)

The theoretical investigations on the influence of the mass ratios and the Froude number on the filling process have been concluded by Dipl.-Ing. K.-H. Fu. The results are available in report form [48].

Dipl.-Ing. G. Braun continued his work on "Data Storage and Retrieval Program" for the exchange of data and test results with the U. S. Air Force regarding scale influences with parachutes [63, 64]. His work is being supported by scientists at the Computation Center Braunschweig.

We could not carry out any full scale parachute experiments, because of other requirements primarily because of (0127), which had priority for the German Defense Ministry.

Dipl.-Ing. G. Braun carried out the first model experiments with the horizontal free flight test installation at a velocity over 100 m/sec. (Figure 5).

2.3 Strength of parachutes (081 0114)

The work is concentrated on the determination of the influence of elasticity of the components of a parachute on the filling forces. In a test program, we prestressed the shroud lines with 80% of the fracture load before the experiment, and the remaining length extension amounted to about 10% (fracture extension about 30%). In the second program, the shroud lines were replaced by steel wires between the load and the base of the cap. The expected higher filling forces did not occur. In another program, we will now replace the shroud lines above the cap by steel cords. At the present time we are producing shroud lines with a small modulus of elasticity. We plan an additional drop test with drop velocities higher than what was possible up to the present.

2.4 Stability of recovery systems (081 0116)

The three-component measurements with flexible parachute models carried out the year before were evaluated (Dipl.-Ing. D. Schmerwitz). The planned theoretical investigations of the pendulum behavior of parachute-load systems had to be interrupted because of the project tasks for (0152). Work on the dynamic stability of parachute-load systems (pendulum oscillations) was summarized by Dipl.-Ing. K.-F. Doherr [45, 46] and Dr.-Ing. P. Hamel [50] in the form of institute reports.

2.5 Ejection seat systems (081 0117)

In the area of analysis of ejection seat subsystems, we carried out experiments using the recovery parachute system of the GW-6A ejection seat. This was done within the framework of accident investigation. The results were obtained in conjunction with the Institute for Aircraft Construction, Braunschweig (Ing. (grad.) H.-J. Seifert). The results were discussed with the customer in several sessions (Dipl.-Ing. U. Schmidt).

The statistical accident investigations of aircraft with ejection seats were concluded by Dipl.-Ing. W. Beduhn and summarized in a report [39].

Ing.(grad.) L. Böhm prepared statistics on helicopter accidents in West Germany since 1958 for the investigation of rescue possibilities from helicopters. Dipl.-Ing. H.-D. Melzig formed an analysis of the accident causes and initial conditions (flight altitudes, flight velocity, flight attitude) in order to evaluate the possible rescue systems. At the beginning of 1973 a report was issued which is a contribution for the AGARD Working Group on Escape Measures for Combat Helicopter Crews.

The experiments with tearing elements for energy absorption during parachute unfolding were concluded and the results were summarized in a report [43]. /103

2.6 Jump parachutes for low deployment heights (081 0118) (081 0118)

The 73 drop tests using single, double and triple parachute systems carried out up to the present have been evaluated. The results show that, if the nominal total cap area is maintained, a bundling of parachutes leads to a considerable reduction in the altitude loss. Drops from only 30 meters were successful (Figure 6). By using several parachute caps, great system reliability is achieved. A final report is in preparation (Ing. (grad.) R. Koch).

At the same time Dipl.-Ing. K.-H. Fu carried out an exact analysis of success phases of a drop, using a specially developed computer program.

R. Oliva investigated the design and method of operation of the "Spreading Gun", a pyrotechnic-ballistic filling aid for parachutes, developed by the firm Stencel Aero Engineering, Asheville, North Carolina, USA. In addition, instructions are given how this device can be appropriately installed in a parachute. The results of tests are given in [12] and a 40% reduction in the filling time was achieved.

2.7 Parachutes for low air densities (081 0127)

A drop sequence was carried out at an altitude of 6,000 m during an extensive test program. Because of the size of the required test area and the required radar control, we used the area around Cazaux-Biscarosse in France for this purpose. Since we were able to carry out the test flights using IMC, we were able to carry out 16 tests with the complete parachute system of the F 104 ejection seat and with a standard comparison parachute in three weeks. The results show that the filling forces at an altitude of 6 km are twice as high for the same stagnation pressure as is the case at sea level. (Dipl.-Ing. H.-D. Melzig, Dipl.-Ing. W. Beduhn, Ing.(grad.) R. Koch) (Figure 7). For the flight test program it was necessary to develop special instrumented projectiles which had to satisfy the difficult icing conditions and the reliability and function requirements of the French authorities (Dipl.-Ing. H.-J. Klewe, Ing.(grad.) D. Münscher). The evaluations, analyses and recommendations for improved recovery systems are being prepared for the client.

2.8 Rescue parachutes (081 0135)

Based on an analysis of the requirements and the deployment limits of available rescue parachutes, we established a preliminary design. It was discussed at the meeting with representatives from the military authorities [30]. During the next phase, a prototype will be developed (P. Hoenen).

Additional experiments are needed in the framework of the investigation of the rescue parachute for aircraft. The results are given in three reports [54, 60, 65].

2.9 Development of systems for the recovery of payloads and rockets from large altitudes and for high velocities (081 0152)

The development of recovery systems for stabilized payloads of high altitude rockets is being continued by Dipl.-Ing. K.-F. Doherr, Ing.(grad.) D. Münscher. The concept studies contained flight trajectory calculations and wind tunnel measurements for subsonic and supersonic velocities and verified the fact that the task could be carried out. A first version of the recovery system was built for flight tests. Drop tests were carried out from an altitude up to 6 km (Figure 8). The newly developed instrumented projectile FB-8 (Figure 9) was used to carry the experiments. In the summer we first carried out the flight tests of the instrumented projectile FB-8. After this we started testing the rocket recovery system. After several successful recoveries, a commercially available pyrotechnic

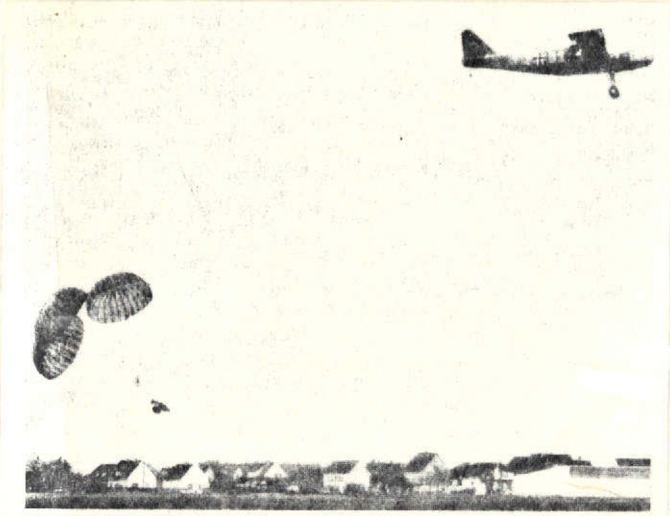

Figure 6. Drop of a 100 kg dummy from a 3 parachute system from an altitude of 30 m.

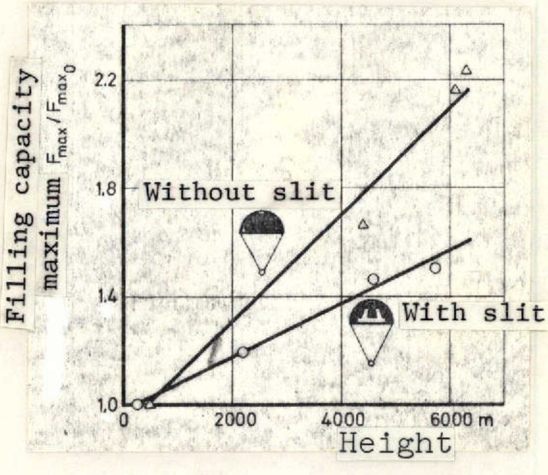

Figure 7. Flight experiment results on the variation of the filling capacity maximum F_{max} of parachutes for humans as a function of the drop altitude for the same initial stagnation pressure. The version with the slit can be controlled.

separation mechanism failed and caused a crash, and the instrumented projectile was very heavily damaged. In the meantime, work on the construction of a new instrumented projectile has started and it will be tested in 1973.

The work mentioned above was carried out within the framework of the "Functional Support" program for the GfW. In addition to the Flight Mechanics Institute, the following DFVLR installations were involved: Mobile Rocket Bases, Oberpfaffenhofen; Aerodynamics Institute, Braunschweig; Flight Control Institute, Braunschweig; Flight Division, Braunschweig and the Central Division for Low Velocity Wind Tunnels.

The firm Rheinmetall GmbH made their test grounds in Unterlüess available for the drop test.

2.10 Industry assignments (081 0140) /104

We investigated the operation and reliability of a new type of gliding parachute (glide coefficient 3) for the firm Autoflug in 31 test drops.

We carried out experiments with rescue parachutes packed in various ways at the request of the firm Autoflug. The task was concluded with final report [55].

Ing.(grad.) J. Friederichs and R. Oliva presented a report [3] on the development and testing of a rescue unit for the instrumented projectile LB-21 "Bumerang I" of the firm ERNO Raumfahrttechnik GmbH.

3. Flight mechanics of aircraft

Dr.-Ing. K. Wilhelm

3.1 General remarks

The modification of the HFB 320-S1 Hansa of the DFVLR was concluded in October (see Section 1.4 of this report). This meant that the HFB 320 was available as an experimental vehicle for determining the coefficients and for the investigation of noise-reducing steep approaches with direct lift control DLC (Figure 10). The preparation and execution of the flight test program represented the greatest part of the work of the division.

3.2 Investigations of V/STOL technology (081 0101)

In the area of V/STOL, we continued the work on the control system investigations using a Direct Side Force Control, DSC. In the case of Direct Side Force Control, the side forces required for control are produced by jet deflection of some of the lifting engines so that sideway deflections and velocities can be controlled without changing the transverse orientation. The related difficulties can be avoided. Dr.-Ing. K. Wilhelm and Dipl.-Ing. R. Koehler determined the optimum control parameters of a linear and of a non-linear controller considering a limited maximum side force. The optimization was based on a cost function, which considers the flight property directives of the AGARD-Report No. 577. This represents an extension of the ITAE criterion, and the quietness of the controls becomes the most important parameter. Since the magnitudes of the initial deviations and velocities influence the variations with time considerably and because the combinations of the initial values occur with various probabilities, the optimization was carried out over an area of the phase plane, and the combined probability of initial deflection and initial velocity were considered. As Figure 11 shows, the linear /105
controller optimized for the phase area has an influence which is too small so that the deflection is controlled too slowly. For large deflections, there is also a strong superimposed vibration. The non-linear controller, on the other hand, produces good controller characteristics [10] for all initial values in the investigated region of the phase plane. Dr.-Ing. K. Wilhelm prepared a summary report [20] on the general flight mechanical problems of STOL aircraft.

3.3 Collaboration with national and international panels for the unification of terms and symbols in flight mechanics (081 0104)

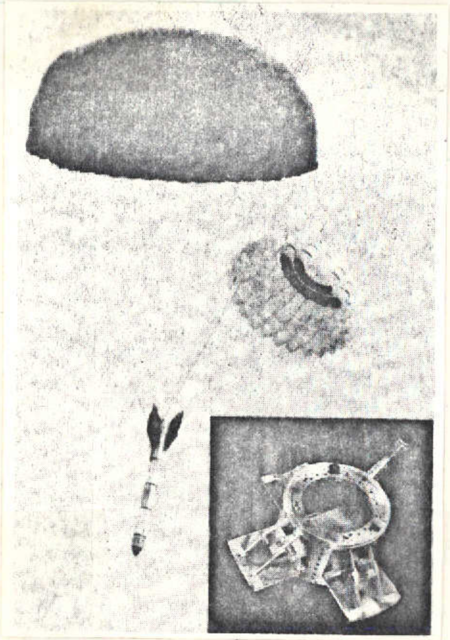

Figure 8. Test of a recovery system for rocket motors. The brake flap section (lower right) is required for delaying the rocket motor during entry into the atmosphere.

The DGLR committee "Nomenclature Determinations in Flight Mechanics" processed the terms for flight measurement variables which occur in aerodynamic data based on an international standard during the year of this report.

The work on standards for the neutral points and stability parameters, as well as the flight measurement variables, was essentially concluded at the international ISO Working Group. Further work will be directed at a unified definition of construction variables, flight phases and disturbances.

Prof. Dr.-Ing. E. Mewes directed the DGLR committee "Nomenclature Determination" and was the German representative to the International Working Group. Dipl.-Ing. G. Rosenau took on this responsibility during the second half of the report year.

3.4 Concept study for V/STOL simulation using helicopters (081 0134)

Investigations on the use of a helicopter as a test stand for simulating V/STOL aircraft were carried out. The determination of the simulation range was the most important factor in the studies. Dipl.-Phys. M. Marchand developed a digital program which calculates the required control variables of the helicopter for prescribed flight maneuvers. At the same time,

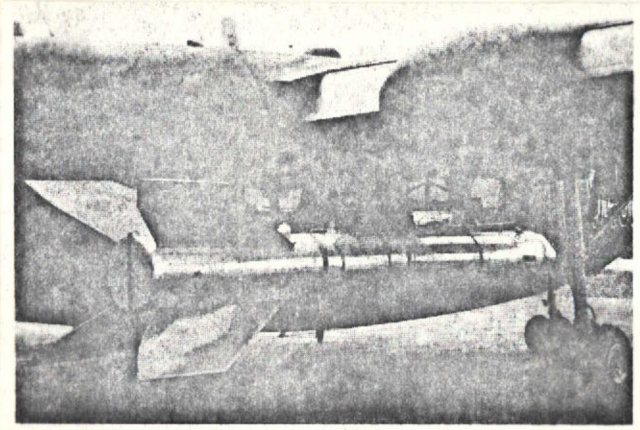

Figure 9. Test projectile FB-8 for testing recovery systems for rocket tables and rocket motors.

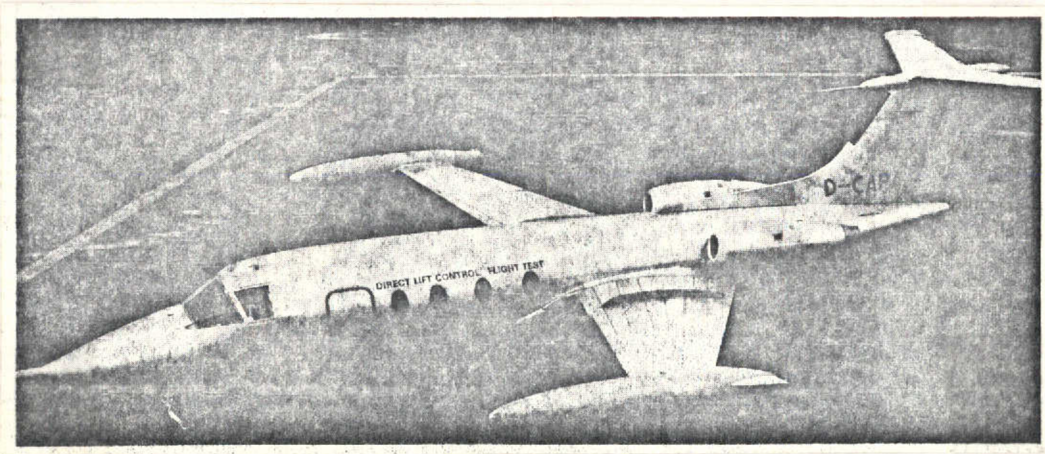

Figure 10. Research aircraft HFB 320-S1 of the DFVLR.

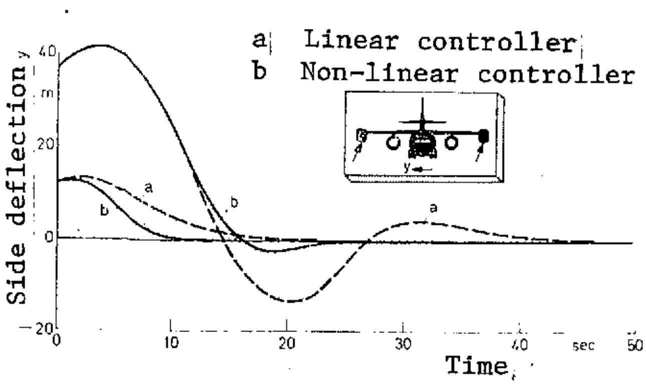

Figure 11. Direct side force control for compensating the side deflection of a VTOL aircraft (from [10]).

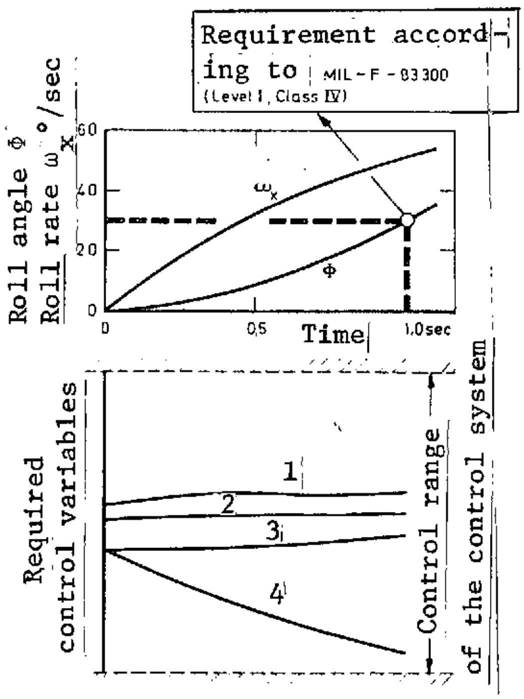

Figure 12. Simulation of a prescribed roll angle variation for the helicopter BO 105.

1- pitch control, 2- collector's blade displacement, 3- yaw control, 4- roll control.

it determines the motion variables by integration. These cannot be specified because there is no suitable control capability. For the investigations during hovering flight and in the transition range, the helicopter model was adapted by interpolation of the prevailing velocity. The maximum possible acceleration values to be simulated can be found from the calculated variation of the control variables. For example, Figure 12 shows the variation of the four control variables of the helicopter BO 105 for a prescribed roll angle variation, which is the most stringent requirement (30° per second) in the MIL-F-83,300 specifications. The control variables remain in the permissible range; however, the roll control almost hits the stop because increased control moments are required with increasing angular velocity, because of the roll damping. In addition, we investigated whether helicopters can simulate the eigen motions of V/STOL aircraft. The position of the poles for V/STOL aircraft was varied over the possible range. The simulation range can then be specified from the calculated amplitudes of the control variables. A final report is being prepared.

3.5 Gust reduction systems (081 0144)

An aircraft with good flight handling characteristics must be as insensitive as possible to gust disturbances. Often the natural flight properties of modern aircraft are not sufficient in this regard. Therefore, open loop control loops must be used for active gust reduction with perturbation value inputs. Also closed control systems can be used. Open control loops with perturbation variable inputs only change the gust response behavior of the aircraft, but not its other flight properties; the use of such a system is complicated by the requirements for a perfect measurement of the gust disturbances. When closed control systems are used for gust reduction, it is only necessary to measure the gust effects on the flight motions, which are easier to measure than the gusts themselves. In general, the flight properties will change due to the control. This is not desirable. While he was a guest at the ONERA at Chatillon in France, Dipl.-Ing. G. Rosenau became familiar with the optimized control methods used there [62]. Starting with a flight controller with tuned lift control (production of an aerodynamic control force at the neutral point of the aircraft), a perturbation variable input method was combined with a method which is supposed to avoid the disadvantages of pure control and pure regulation. The elastic deformations of the aircraft were also considered (see 0143, Section II.1.3 of this report). /106

In the report year we also started with preliminary investigations of the simulation of flight in turbulent air using a wind tunnel. Basic problems in the area of gust reduction will be

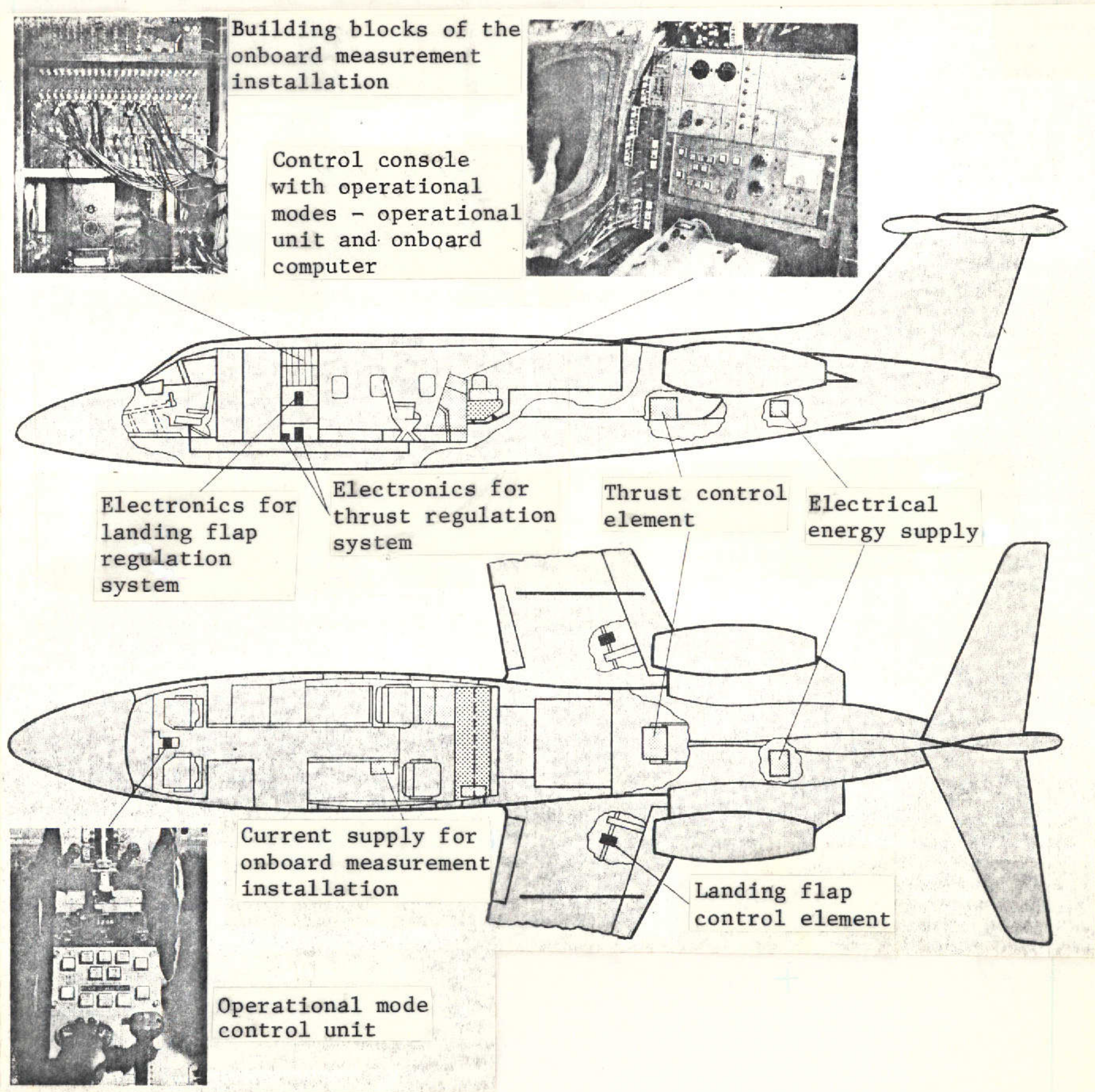

Figure 13. Representation of the systems integration carried out within the framework of the first redesigned phase with the research aircraft HFB 320-S1.

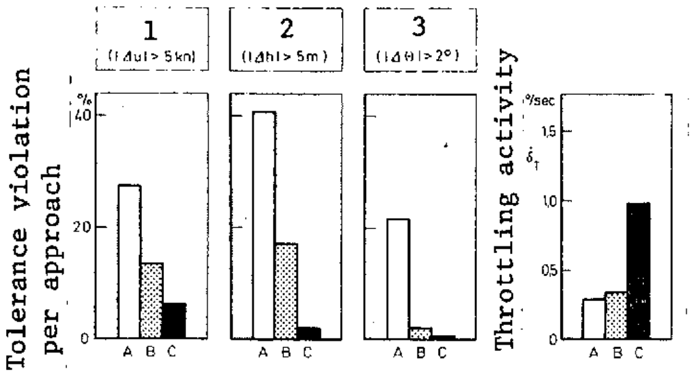

Figure 14. Simulation results with the research aircraft HFB 320-S1 for landing approach. Percentage of exceeding the tolerance limits per approach (A = elevator control, B = lift control, C = lift control with automatic course maintenance).

1- course violation, 2- glide path violation, 3- longitudinal inclination violation.

investigated using a flexible aircraft model in a wind tunnel and in conjunction with the Central Division for low velocity wind tunnels. The aircraft model will first be equipped with control surfaces and servomotors.

The work on the representation of the transfer behavior of the linear system using eigen vectors has been concluded. The results were published in a research report [14]. The corresponding computer program is contained in an internal report [61].

3.6 Aircraft with variable flight properties (081 0147)

The first phase of the modification of the HFB 320-S1 Hansa of the DFVLR into an aircraft with variable flight properties has been concluded in October, 1972 under the direction of Dipl.-Ing. D. Hanke [28] (Figure 13). At the request of the

German Defense Minister, electrical landing flap systems and thrust regulation systems were installed at the facilities of Messerschmitt-Bölkow-Blohm, Hamburg Division (MBB-UH). In addition, the electric energy supply system for the electrical control systems has been expanded. At the same time Dipl.-Ing. J. Schott and Ing.(grad.) K. Moser (Institute for Flight System Dynamics, Oberpfaffenhofen) developed an electrical operational mode control system and surveillance system (BBG) for the electrical servo systems. The Aircraft Flight Mechanics /107
Division (Ing.(grad.) M. Müller) installed the units and a control console for the BBG. The integration of the electrical systems in the aircraft and the expansion of the onboard measurement installation and telemetry system were carried out by the Flight Test Technology Division (see Section II.5 of this report). After concluding the ground tests of the individual systems and after a demonstration for the Federal Aviation authorities (LBA), the functional tests of the electrical servo systems were demonstrated in flight in December of 1972. This means that the HFB 320-S1 is now available as an experimental flight vehicle for determining coefficients. It can also be used to test direct lift control constants. The test flights were carried out during the report year by the pilots Dipl.-Ing. P. Joenck (Institute for Piloting, Braunschweig) and Ing. G. Puhlmann (LBA). Dipl.-Ing. H.-H. Lange, Dipl.-Ing. H. Meyer and Dipl.-Ing. D. Hanke were the test engineers.

As a preparation for the flight test program HFB 320-S1, Dipl.-Ing. D. Hanke and Dipl.-Ing. H. H. Lange carried out simulation investigations using a fixed simulator of the Flight Mechanics Institute in which various direct lift control concepts were evaluated [5]. The controllability of the DLC concepts was evaluated during simulated landing approaches with gust influences. The statistical evaluation of the simulation data is shown in Figure 14. This is a histogram for the four following characteristic variables: maintenance of the course deviation, maintenance of the glide path and maintenance of the pitch angle. Also the throttling activity is shown. As the simulation results show, it was possible to maintain the course more accurately, especially under the influences of gusts, by coupling the elevator with the landing flap. Compared with the elevator control (A), the deviation per approach from the nominal conditions was considerably reduced using the DLC control with the connection of the elevator and the flap. By using an automatic course maintenance system during DLC approaches (C), it was possible to improve the course maintenance accuracy even more. However, the throttling activity was quite high because of the large regulation authority of the forward thrust regulator.

Dipl.-Ing. H.-H. Lange performed a theoretical analysis of the forward thrust regulator for the HFB 320-S1 as a diploma thesis at the Flight Mechanics Institute of the Technical University, Braunschweig. The forward thrust regulator was programmed and the hardware was tested in simulations using an onboard analog computer built by the Flight Test Technology Division and which is to be used for the Hansa flight test. Dipl.-Ing. H.-H. Lange took over the hybrid simulation of the mathematical model of the Hansa, which was made possible by the use of the new hybrid computer installation EAI PACER 600 of the computer center. The mathematical model of the HFB 320-S1 Hansa was developed by Dipl.-Phys. M. Marchand. This model is based on wind tunnel data. It is non-linear and is valid for a wide region of polars. Based on this model, a digital program was built which calculates all the interesting variables for prescribed reference states. Also it makes possible to establish a valid linear model for this state. The model found was improved by evaluating flight tests.

The flight tests of the direct lift control (DLC) during noise-reducing steep approach trajectories were started in December. Figure 15 shows a strip recording of the responses of the Hansa due to pure elevator deflection as compared with elevator deflection with connected landing flap.

The aircraft behavior change brought about by DLC control and for the same elevator input amplitude is manifested by the reduced pitch attitude change by a steeper increase and larger magnitude of the vertical acceleration and by the large trajectory angle changes. The vertical acceleration with DLC is greater by more than 0.1 g than with the elevator control. The changed variation of the angle of attack can be seen which is a consequence of the lifting motion generated by the flap lift. The behavior predicted by the simulation was verified by flight tests.

The determination of the coefficients is another important activity of the division. Dipl.-Phys. M. Marchand used the static frequency variation method for evaluating flight tests with the Do 27 and the HFB 320 [11]. The evaluation of the first flight tests with the HFB 320 carried out by the Flight Mechanics Institute showed that the model obtained from the flight tests results in a better agreement with the pitch responses obtained during flight tests than those measured on a model in a wind tunnel (Figure 16). We intend to improve the HFB 320 model /108
by further flight tests using longer statistical excitations of the flap and the elevator and for various reference states. The reference states will be varied in steps.

Dipl.-Ing. R. Koehler used the model with the automatic parameter adjustment, in order to determine the derivatives of the longitudinal motion of a Do 27 obtained during flight tests. The analysis was first carried out using a linear model. A second analysis included terms proportional to α^2 (α = angle of attack). A comparison of the results shows that, by considering the derivative $C_{X\alpha^2}$, the fluctuations in the model parameter $C_{X\alpha}$ decrease greatly (Figure 17). The linear model of the X-force equation therefore only resulted in an insufficient description of the processes. A paper was presented on the results [9] and a research report was prepared [8].

3.7 Evaluation of aircraft projects (081 0148)

Research projects and other projects for the German Defense Ministry carried out by industry have been analyzed and evaluated within the framework of the future aviation technology program (ZTL), (Dipl.-Ing. R. Koehler, Dipl.-Phys. M. Marchand, Dipl.-Ing. G. Rosenau, Dr.-Ing. K. Wilhelm).

The possibilities of a test program and an experimental program using the Do 31-E 3 were investigated to support a future V/STOL transport system, in conjunction with the firm Dornier and other DFVLR divisions (Dr.-Ing. P. Hamel, Dr.-Ing, K. Wilhelm).

Towards the end of the report year, the MRCA program in the areas of flight performance, flight properties and flight control were started, which is a technical support of the German Defense Ministry (Dr.-Ing. P. Hamel).

3.8 Maneuver investigations

The accelerations with changes in sign which occur during certain maneuvers in the cargo area of the aircraft Transall C-160 have been analyzed in a more exact way. Dipl.-Ing R. Koehler and Dipl.-Phys. M. Marchand simulated the longitudinal motion of the Transall using the hybrid computer. As the investigations show, it is possible to avoid the undesirable acceleration changes in the cargo area by means of a specially tuned lift control system. Flight experiments with a Transall are being prepared in order to clarify the problems and formulate recommendations. These tests will be carried out at the beginning of next year.

3.9 Theoretical and experimental investigations of the ground resonance theory of helicopters (081 0105) (1971)

By ground resonance we mean oscillation phenomena which can occur during the takeoff and landing of helicopters. They have often led to accidents and are therefore of special interest. Dipl.-Ing. R. Schröder carried out an investigation within the framework of this task. He determined the effect of additional degrees of freedom on the oscillation behavior, which is usually not described by the commonly used plane replacement systems.

The investigations were concluded in the report year. The results which were available at the beginning of the year were complemented by additional evaluations of data. Also analytical and numberical calculations were performed [15].

3.10 Performance and analyses of domestic and foreign aircraft types.

The work on the comparison of flight performance and flight properties requirements for the aircraft type Concorde and those of conventional aircraft were summarized in a final report by Dr.-Ing. H. Herb [53].

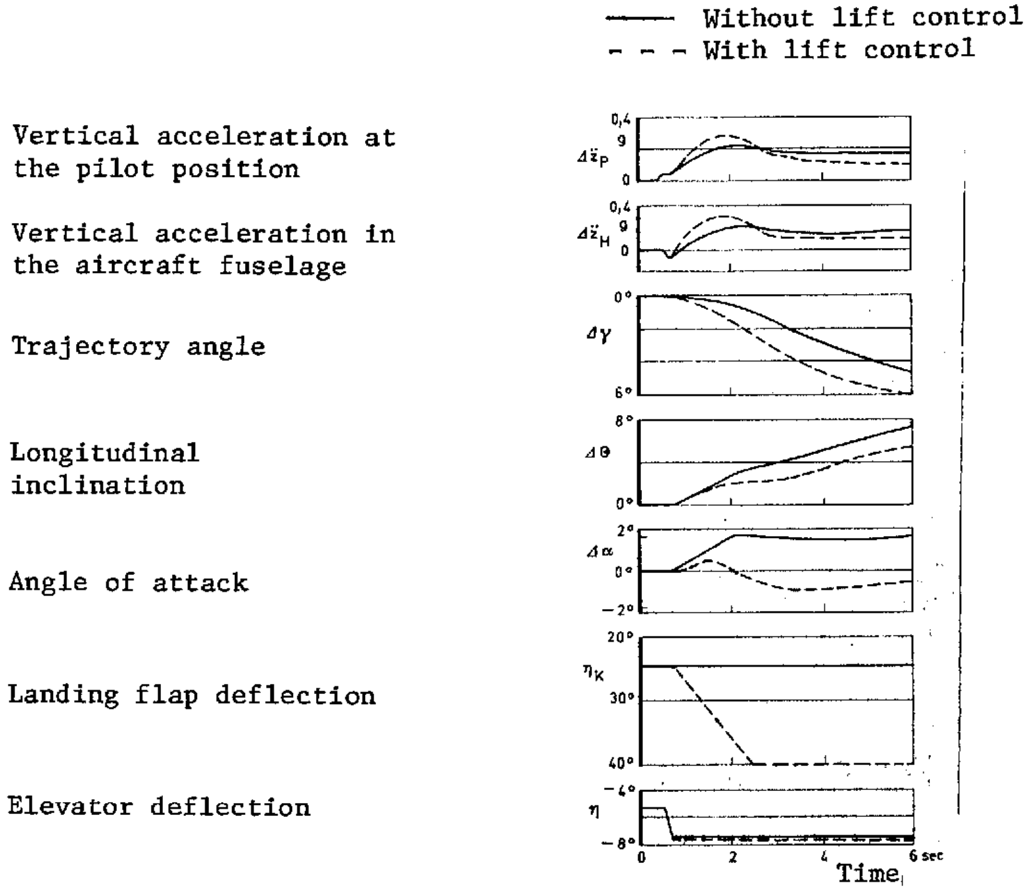

Figure 15. Flight test results with the research aircraft HFB 320-S1. Responses of the aircraft on an elevator jump input with and without lift control.

3.11 History of aviation

Dr.-Ing. H. Herb gave a lecture on problems in the history of flight mechanics [29] within the framework of a colloquium at the Research Center.

4. System analyses

Mrs. Dr.rer.nat. E. Schwarz

4.1 General remarks

Just as in previous years, the division primarily works on technical systems, their analyses, evaluation and also on their optimization.

In addition to the topics contained in the research plan for 1972, Math. F. Hammelrath in conjunction with Dipl.- Ing. L. von Bönin and Dr.-Ing. N. Schmidt (both Institute for Propulsion Systems, Braunschweig) performed a study on systems technology work of the DFVLR at the request of the Science and Technology Division. The jointly prepared report shows that it is necessary to consider systems technology approaches in a large number of research projects. A further development of these ideas is desirable.

4.2 Evaluation of technical systems (081 0119)

Several full reports of test facilities and firms on anti-aircraft systems, additional systems for existing aircraft were evaluated at the request of the German Defense Ministry. Dr.rer. nat. E. Schwarz and Dipl.-Math. G. Wulff made three contributions.

Dr.rer.nat. E. Schwarz worked on an optimization problem for a NATO study group. He gave lectures at three international meetings and prepared written reports. Math. F. Hammelrath developed an optically operating simulation model for the same NATO group.

Evasion maneuvers of targets have a large effect on the effectiveness of anti-aircraft installations. Math F. Hammelrath

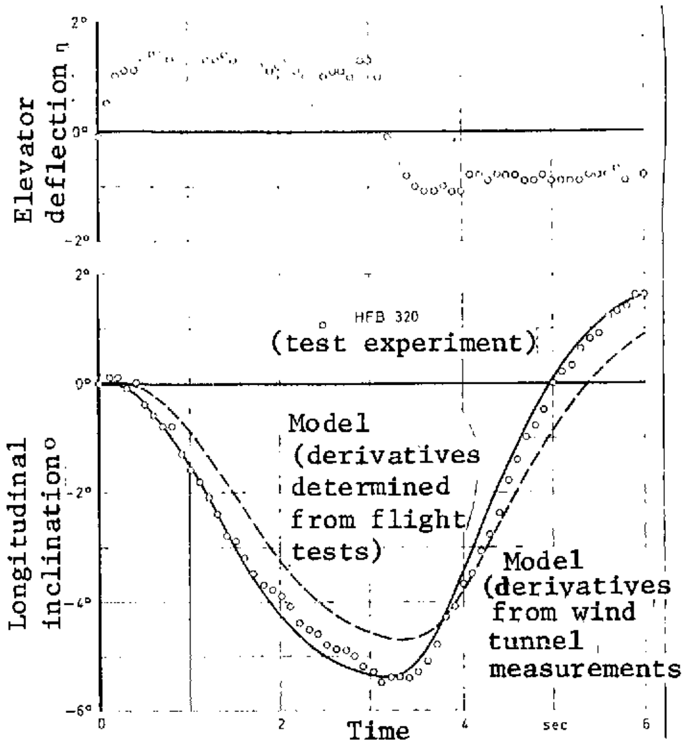

Figure 16. Comparison of the responses of the longitudinal inclination (pitch position) of the research aircraft HFB 320-S1 measured during flight tests and the responses of a model determined from flight experiments and wind tunnel measurements (from [11]).

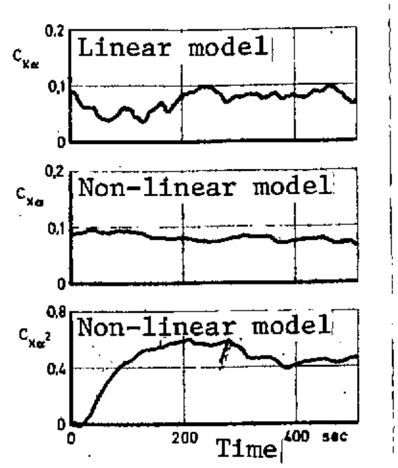

Figure 17. Influence of the mathematical model on the quality of the determined coefficients, shown for the example of the derivative C_{Xa} of the aircraft Do 27 (Koehler method [8,9]).

and H. Moch performed calculations which showed how much an aircraft can reduce the hit probability of anti-aircraft defenses by performing specified maneuvers. It is assumed that the anti-aircraft will use the classical anti-aircraft defense hypothesis of flight along a straight line. Part of these calculations were carried out at the request of the firm VFW in Bremen. Investigations are being carried out on other extrapolation possibilities of the observed target motion, and of the subsequent improvement in the hit probability of the anti-aircraft defenses.

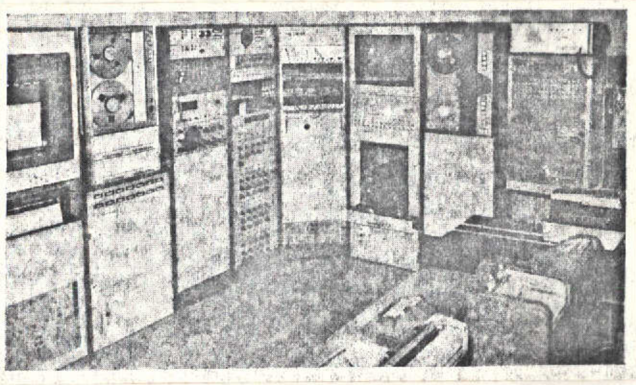

Figure 18. Data processing installation of the flight test technology division.

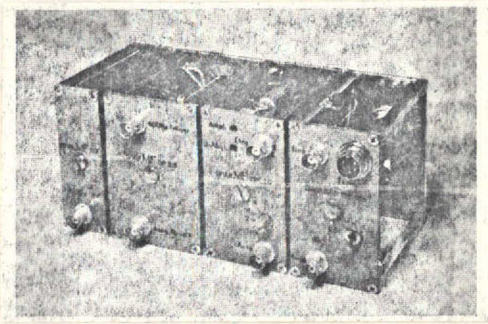

Figure 19. Building blocks of the flexible onboard measurement system.

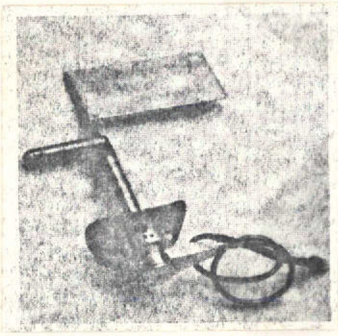

Figure 20. Newly developed flow direction transducer for aircraft state measurements of the research aircraft HFB 320-S1.

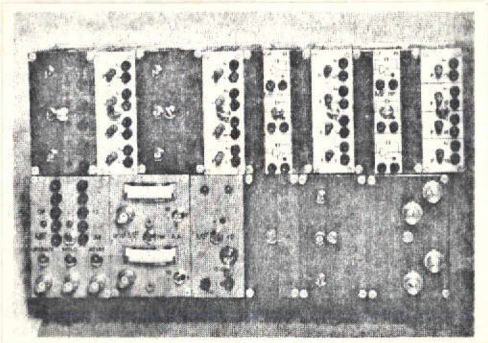

Figure 21. Analog computer in the building block system for tasks assigned to the research aircraft HFB 320-S1.

4.3 Engine model (081 0120)

After a model has been developed for a certain engine, the methods developed are applied to another type of engine. The geometry of the new engine must be described again ("geometric model") and the functional relationships must be tested, especially those of the engine periphery. The functional model must also be modified. Of all these tasks which must be done over for each engine, the geometric description of the engine periphery has already been carried out. The new formulation of the functional model is now being done (Math. F. Hammelrath, Dipl.-Ing. Ch. Doukas and J. Buchholz).

4.4 Reliability questions (081 0122)

Math. F. Hammelrath developed a design of "state models" within the framework of his collaboration at the VDI/VDE committee "reliability". It is believed that this will appear as a green report, a VDI directive report.

4.5 Time sharing (081 0128)

In order to test user computer systems capable of dialog interaction, we operated the CDC image screen terminal, which is connected with the data processing facility of the IABG in Ottobrun. It was applied to various problems in process within the division. We were very interested in heuristic methods during this last test phase, in which human beings always control the progress of the program, corresponding to his limited capabilities (Math. F. Hammelrath).

4.6 Air traffic planning (081 0136)

During the report year, Dipl.-Ing. Ch. Doukas used the forecasting method of Bayart for problems in air freight and air postal service [47]. The point of departure for a so-called dynamic trend extrapolation of Bayart is the possible method of trend extrapolation with subsequent corrections for seasonal indices. However, this is associated with certain drawbacks, such as for example, long time series and trend developments which have to be represented by analytical formulas. The present method attempts to avoid these drawbacks and provides a short term forecasting method, which uses relatively small amounts of data and can easily be programmed on an electronic computer. Because of personnel restrictions, no further contributions to aircraft can be made at the present time. On the other hand, the advisory service for the Central Division for Aviation Technology, Air Traffic Science Division, in Stuttgart is being continued.

4.7 Comparative evaluation of research and development projects

Dipl.-Math. H. Wolff concluded the work on glass reinforced plastics with an internal report which was given to the customer (German Defense Ministry). This work had started in the report year 1971 in order to evaluate and clarify research and development projects. About 200 research and development reports from various industrial divisions and research centers were collected and evaluated [70] within the framework of this activity. We found that the execution of such projects depends greatly on the information potential and on the availability and quality of the research and development reports.

5. Flight test technology
Dipl.-Ing. H. Meyer

5.1 General remarks

Most of the work carried out by the division involved measurement technology and the collection and preparation of flight measurement data for the flight tests carried out within the framework of the investigations of aircraft flight mechanics. The new construction of a stationary data process- /110 ing installation (Figure 18) represented another major task. This installation is connected by means of a cable with the newly acquired hybrid computer EAIPACER 600 of the computer center, Braunschweig. In addition, we have taken on the integration and support of a few of the electronic subsystems for the research aircraft HFB 320-S1.

5.2 Measurement technology and test technology for flight experiments and parachute experiments (081 0124)

In order to shorten the measurement acquisition times and installation times for flight experiments in the determination of flight performance and flight properties of various aircraft, we designed and built a compact and flexible onboard measurement system. A simple measurement installation can be installed in an aircraft within a few days by using combinations of standardized building blocks. The standardization was carried out with respect to the dimensions, connection plugs, supply voltages, input and output arrangements and input and output levels. Because of the construction, the circuit boards are accessible from both sides and are simple to operate. At the present time the system is an analog system and consists of components such as matching and controller amplifiers, filters, demodulators, strain gauge bridge amplifiers, attenuators, voltage supply units, signal generators, calculation circuits and FM telemetry components. The system was first introduced during the report year at the air show at Hannover. Figure 19 shows a few of these building blocks.

For the research aircraft HFB 320-S1, we designed new wind vanes for measurement of angle of attack and angle of side slip (Figure 20). We also developed calculation components for determining the nominal trajectory angle from the longitudinal inclination and angle of attack signals and for the determination of the potential trajectory angle from the longitudinal and vertical acceleration signals and the angle of attack signals.

5.3 Systems integration (081 0149)

Flight tests for determination of coefficients were carried out with a Do 27 using the onboard system described in Section 5.2 and the ground system described in Figure 18. At the end of the year, we carried out system tests and flight tests using the HFB 320. Part of the onboard measurement installation of the HFB 320 can be seen in the representation given in Figure 13. It was built up out of building block systems and can collect 24 signals.

Ing.(grad.) B. Gartung was responsible for the electronics and the integration of various subsystems delivered by industry for the "variable flight property aircraft" (0147) project for the research aircraft HFB 320. Among these we have the landing flap servo system, the thrust servo system, the electrical energy supply and the operational mode control console built by the Flight System Dynamics Institute.

The landing flap system and the thrust servo system were successfully tested during the first phase of the flight test program with the HFB 320 (see Section II.3.6 of this report). Experiments with variable elevator-landing flap connections and thrust input switchings were started. An analog computer based on the building block system was also conceived and built. Figure 21 shows the computer at the laboratory to be used for simulation with the hybrid computer EAIPACER 600 of the Computer Center, Braunschweig. It can be seen in Figure 13 to the left next to the control console, in a very compact arrangement.

6. Rotating wing systems

Prof. Dr.-Ing.habil. W. Just (up to July 31, 1972)
Dipl.-Ing. H. Georgi (Commission basis after August 1, 1972)

6.1 General remarks

During the report year, the work was essentially influenced by the assimilation of the previous rotary wing aircraft institute at Stuttgart which occurred during the reorganization of DFVLR on August 1, 1972. It was integrated with the Flight Mechanics Institute at Braunschweig. In the spring of 1973, the "Rotary Wing Aircraft" group was moved from Stuttgart to Braunschweig. Preparations of the discussions on the organization and moving of the institute within various panels took a great deal of time. After successful reorganization, the future of helicopter research and personal problems of the scientists became important at the DFVLR. We expect that due to the present structure and the economy measures which have been taken, there will be partial elimination and modification of the main research projects in the area of rotary wing aircraft. This is also because of the new aviation research program of the Federal Government.

6.2 Mutual influence of the rotor and wings, lifting surface theory (027 0114) /111

The asymmetry of the incident rotor flow during forward flight leads to high fluctuating aerodynamic forces as the velocity is increased and to oscillation loads on the rotor blades. In spite of excessive propulsion capacity of the engines, velocities above about 350 km/h will not be possible for conventional helicopter designs. In addition, the capacity of blades connected with joints or of elastic blades connected without joints to produce lift decreases as the performance coefficient (ratio of flight velocity to circumferential velocity of the rotor) is increased. In order to increase the velocity, it is necessary to unload the rotor by additional forward propulsion and lift aids. Such devices are known as compound helicopters. With these devices, it is necessary to consider the mutual influence of the rotor and the unloading wings by induction. This must be considered in addition to the difficulties of an accurate theoretical determination of the rotor forces and moments considering the rearward flow, the unsteady effects and the influences of Mach number. The unloading wings should only produce lift at higher velocities and therefore can be relatively small. The lift calculation using the lifting line theory is not accurate enough because of the small aspect ratio. This is why Dipl.-Lng. H. Bergmann developed a method of calculating the downwind field at the location of the lifting wing considering the influence of the rotor downwind. A comparison was made between the results obtained with the lifting line theory [40] and the forces and moments at the wing determined with the lifting surface theory.

6.3 Influence of the rotor angle of sideslip on the rotor forces and rotor moments (027 0122)

This research project was delayed in order to work on icing problems.

6.4 Influence of unsteady effects on the rotor forces and rotor moments (027 0123)

Because of the rapidly changing incident flow conditions at the rotor blade during circulation, the forces and moments at the rotor are influenced by unsteady effects for almost all flight states. The dynamic effects are most important for high performance rotors, which are operated at large circular area loads and velocities. This leads to a subsequent flow separation over the profile and this conversely produces a high load on the blade. The oscillations of the blade profile essentially consist of two components: a pitch oscillation around the blade spar axis due to the cyclical control and a torsion of the blade due to the large pressure point fluctuations in the separation region, as well as a transverse oscillation made up of blade flapping motions and elastic blade bending oscillations. The superposition of these fast angle of attack oscillations can lead to a forced angle of attack hysteresis with negative damping of the pitch angle oscillation after the unsteady maximum lift value is exceeded. The theoretical treatment of this process is complicated. Quasisteady methods based on potential theory are only sufficient for small angles of attack because the friction can be ignored. Existing unsteady three-dimensional theories are usually inaccurate. In the case of the helicopter, there is also the influence of induction of the various vortex layers which is difficult to describe. The knowledge of the influence of unsteady aerodynamic forces is especially important for determining the rotor blade loadsand in order to determine the aeroelastic instabilities (divergence, flutter). The blade bending moments in the flapping direction can be calculated considering local angle of attack changes due to the blade flapping oscillations [49] using a computer program designed by Dipl.-Lng. B. Gmelin. Figure 22 shows the blade bending moments M_β of a jointless model rotor blade using stationary profile coefficients and calculated according to the transition matrix method. Considering the blade elasticity and the variable downwind field according to a theory of Scully, there is good agreement between the calculation and the measurements. Assuming a rigid rotor blade and a constant downwind distribution, the agreement is not satisfactory. An extension of this work will determine whether unsteady profile coefficients obtained from dynamic measurements could improve the calculation results.

6.5 Design of computer program (027 0125)

The calculation of aerodynamic loads of helicopter rotors in various operational states, such as hovering, ascending flight, descending flight, forward flight, during controlled maneuvers and under the influences of gusts can only be done with sufficient accuracy by considering numerous motion degrees of freedom. This is because of the complicated motion of the helicopter itself and the motion of the rotor blades. In order to perform performance, control and stability investigations, Dipl.-Ing. O. Storm developed a calculation method with which compound configurations with unloading wings and additional thrust can be treated in one-rotor and coaxial configurations. The computation method results in the initial distributions of the aerodynamic forces for blade oscillation calculations [67-69]. Various sample calculations were carried out and were compared with flight measurements. Figure 23 shows that /112

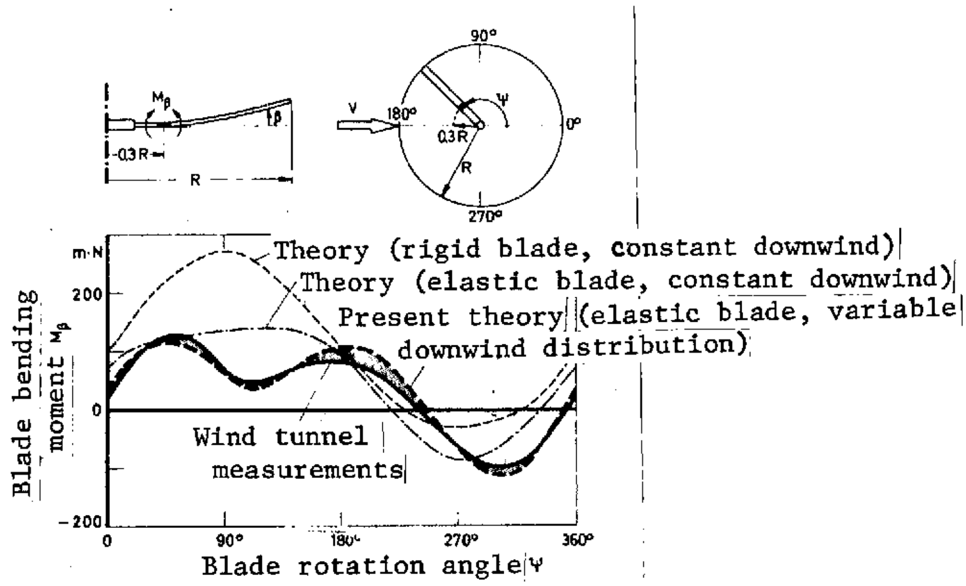

Figure 22. Blade bending moment of a hingeless model rotating blade considering the angle of attack change due to blade bending oscillations. Rotor radius R = 1 m, blade adjustment angle = 6°, flight velocity V = 50 m/sec, blade location at 0.3 R (from [49]).

there is good agreement with the measurements of the dynamic behavior of the HTM Skytrac helicopter.

The blade design for a stopping rotor and a foldable rotor was investigated with a parameter variation in connection with the design of a universal research rotor installation to be installed in a wind tunnel (see Section 6.14).

The optimum blade design with regard to favorable mass and stiffness behavior in order to avoid aeroelastic instabilities during the deployment and folding phase of the rotor constituted a particularly important problem. We found that in order to do this, it is sometimes necessary to have large flapping bending stiffnesses with a very low blade weight. By using a computer method developed by Dipl.-Ing. O. Storm [68], Dipl.-Ing. A. Kussmann optimized several profiles by varying the wall

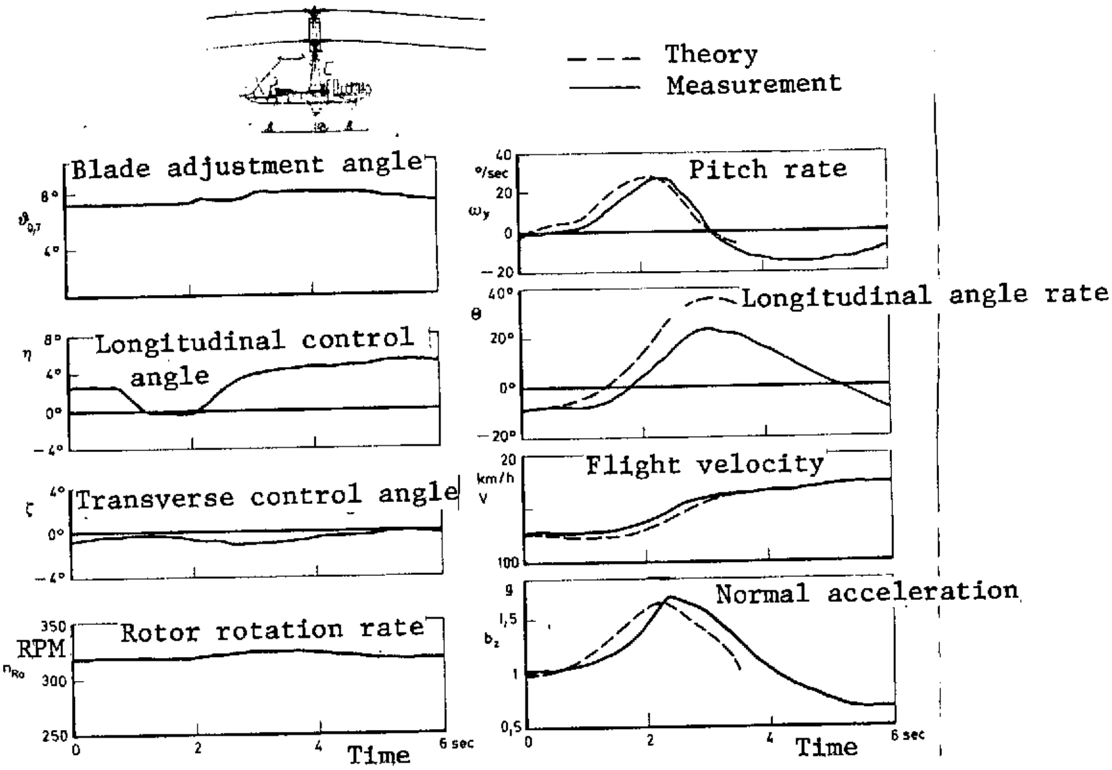

Figure 23. Comparison of measured and calculated responses of the helicopter HTM Skytrac to specific control angle inputs (from [67]).

thickness, spar shape and material. The work on aeroelasticity was performed by Dipl.-Ing. S. Benz. Dipl.-Ing. G. Schilling and Dipl.-Ing. O. Storm calculated the forces and moments over the rotor. A summarizing report is being prepared.

6.6 Control and stability of fast helicopters (027 0104)

As the flight velocity increases, the motions of the rotor blade in the flapping and rotation direction increase continuously and can become unstable. Stopping rotors, in which the restoring centrifugal forces are small or zero during the deployment and idling phases, can have blade deflections which cannot be controlled even for small disturbances if the rotor blade is connected with a joint. This is why jointless connections are used for the blade for such rotors. The blades then have large bending stiffnesses. In order to reduce the computation effort of the jointless blade, it is possible to simulate the dynamic and aerodynamic properties by introducing equivalent joint distances in flight mechanical investigations. The restoring spring forces at the replacement joints are calculated. As a continuation of the investigations started in the previous year which considered the flapping and rotary motions of the blade, Dipl.-Ing. G. Schilling improved the calculations by introducing a variable downwind distribution (flux models). In order to determine the forces and moments for the research rotor (see Section 6.14), corresponding replacement joint systems were specified. An internal report is being written.

The control and stability behavior of stopping and foldable rotors are greatly influenced during the flight phase with slow rotation rates and when the rotor is standing still. Dipl.-Ing. V. Illg calculated the velocity variations, pitch angle variations and angle of attack variations for blades at rest in the swept-back position. He used a momentum activated control. The aerodynamic coefficients were obtained from wind tunnel measurements of the "Rotorjet" model of the Messerschmitt project. This was done in order to determine the influence of the rotor at rest on the flight mechanical properties. A final report is being written.

6.7 Theoretical investigation of regulators for helicopters (027 0105)

The work was delayed because of lack of personnel.

6.8 Calculation of the aeroelastic behavior of stopping rotors (027 0107)

The difficulties associated with determining the aeroelastic behavior of rotor blades are due less to the formulation of elastomechanical models than in the description of the rotor aerodynamics with appropriate downwind models and with the consideration of unsteady aerodynamic forces (see Section 6.4). The vortex layers of all rotor blades below the rotor as well as their mutual induction must be taken into account. Such downwind models require a large degree of computation effort and often the accuracy of the calculated forces and moments is in doubt. Work on the determination of the aeroelastic operational /113 limits of the rotor was continued by Dipl.-Ing. S. Benz during the report year. He particularly stressed the applications.

A calculation method for predicting flutter instabilities and higher flight velocities was developed by Dipl.-Ing. S. Benz and Dipl.-Ing. O. Storm for the Messerschmitt-Bölkow-Blohm, helicopter division, using the work of C. J. Astill and C. F. Niebanck. The program considers the flapping, rotation and torsion degrees of freedom and is based on the consideration of unsteady flow components using the lift loss function of Theodorsen.

6.9 Development of payloads (027 0108)

By using a device developed by Ing.(grad.) K. Czarnowski which was installed in Alouette II helicopter of the Country Police, Baden-Württemberg, we recorded and evaluated load multiples in a continuation of the flights performed in the previous year. The measurement data can be used to develop load configurations for helicopter payloads.

Prof. Dr.-Ing. W. Just reworked existing payload regulations in conjunction with the Standards Office of the Army Aviation authorities (MBL).

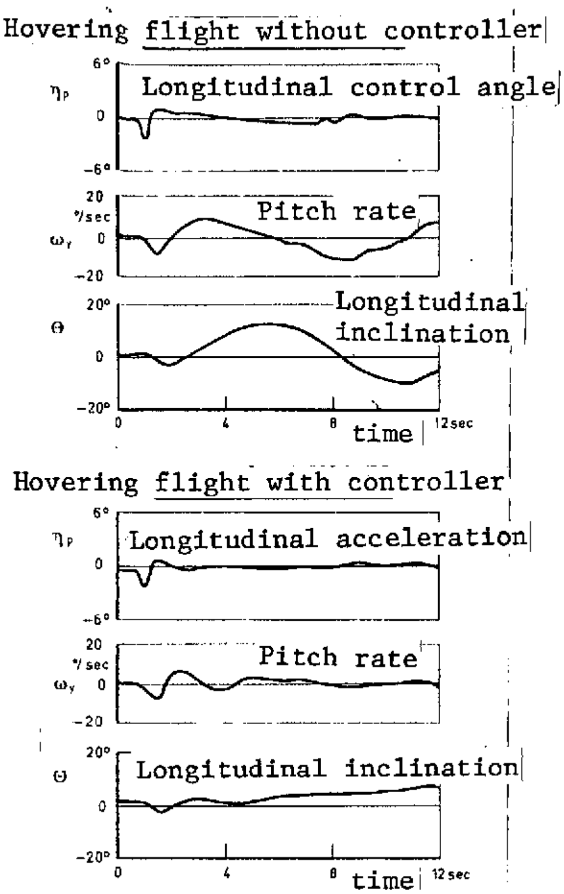

Figure 24. Flight test results on the influence of a control and stabilization installation on the longitudinal motion of the helicopter HTM Skytrac (from [7]).

6.10 Evaluation of the various theoretical and experimental methods for determining helicopter noise (027 0117)

The theoretical rotor noise investigations were done by Dipl.-Ing. H. Bestek. The goal is to produce a basic report [1]. The calculation of the total noise level will be included. These preliminary investigations will be used as a basis for comparisons between calculations and measurements, which are to be carried out on the research rotor using various blade designs. This contribution to environmental control research will require more effort, because numerous rotor design parameters, which are otherwise unimportant, significantly influence the accuracy of a mathematical noise investigation. This is why existing rotor theories must be extended.

6.11 Calculation of coupled blade oscillations (027 0124)

The extensive calculations of rotor blade oscillations were concluded by Dipl.-Ing. H. Oette during the previous report year (see yearly report, 1971, p. 138, section 3.1).

6.12 Flight tests of a regulator installation (Wagner helicopter) (027 0109)

In general, helicopters are dynamically unstable for the lower velocity range, i.e. the pilot must continuously adjust the flight attitude. In order to relieve the pilot, a number of controller installations are being used today, which automatically control the disturbances and maintain the desired flight state of the helicopter.

The regulator installation developed by Prof. Dr.-Ing. W. Bader and Dr. Ing. T. Kallfass and which was tested using the HTM Skytrac is different from the usual regulator installations for helicopters because of an additional control component in the regulator. With this it is possible to prescribe the piloting behavior within certain limits and independent of the stability behavior. With the financial support of the Baden-Württemberg state, a research project was concluded in the report year. The planned testing of the regulator installation for the yaw axis had to be dropped because the Skytrac helicopter was not available.

Figure 24 shows the pulse responses of the helicopter for hovering flight, with and without the stabilization installation as well as the influence of the additional control component.

The flight recordings show that the regulator installation leads to a considerable improvement in the flight properties. The results of the research project were published by Dr.-Ing. T. Kallfass [7, 57].

6.13 Development of small electronic measurement and control devices (027 0112)

During the report period, work was performed on various research projects. As examples: collaboration in the blade oscillation measurements using photoelements, execution of flight measurements of load multiples in police helicopters of the Baden-Württemberg state, work on the control and measurement installation of the research rotor, temperature control for tempering ovens and measurement installation for determining the dielectric constant of cast resins. The last two tasks were done for the Construction Industry Research Institute at Stuttgart.

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6.14 Execution of wind tunnel measurements (027 0118)

In collaboration with the firms MBB-UD, Dornier and VFW, we continued work on a universal research rotor for wind tunnel measurements. The measurements with this rotor have the purpose of studying physical relationships of future rotors which are difficult to describe by theory. We wish to obtain valid data for the design of high performance rotary wing aircraft. At the present time we are performing the following work on rotors: measures for reducing the drag, downwind investigations, flutter investigations, noise investigations, rotor optimization, investigations of stopping rotors, folding rotors, and retractable rotors.

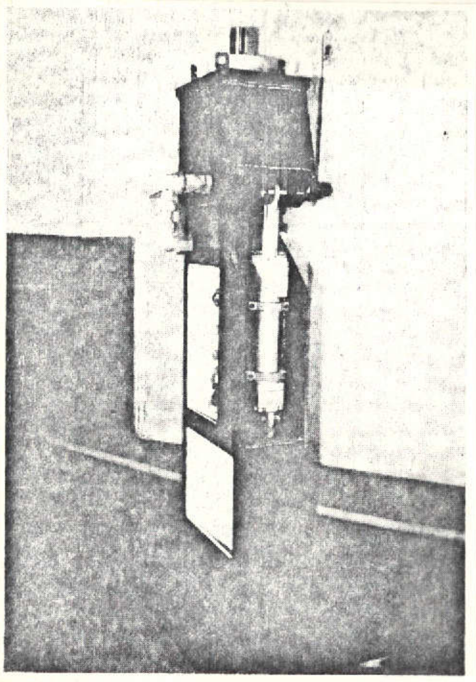

Figure 25. Test stand column with hydraulic tipping device for the universally applicable research rotor (from [56]).

The wind tunnel measurements planned for the report year had to be deferred because of financial reasons. The model installation work has been performed by Dipl.-Ing. R. Jamka and Ing.(grad.) G. Kempe. Important components such as the drive system, support column, hydraulic supply installation and angle of attack tipping mechanism have already been built [56]. The work on the control installations and measurement installations is being continued (torque measurement shaft, coupling-brake combination). The theoretical investigations concerned themselves with the design of rotor blades (rotor forces, mass distributions, stiffness distributions, eigen frequencies, bending moments, etc.).

Figure 25 shows the support column for the research rotor with the tipping device.

6.15 Icing of helicopters

The icing of rotor blades can lead to a significant restriction in the applications of helicopters during wet and cold weather conditions. The icing leads to modifications in the profile contours. Consequently, the drag is increased and the lift is decreased. By changing the mass distribution in the direction of the profile chord, pitch moment changes occur which can lead to oscillation excitation. Asymmetric casting away of the ice can lead to fuselage vibrations.

Because of this problem, the task of determining the influence of the rotor yaw angle on the rotor forces and moments (see Section 6.3) was deferred. The icing problem was analyzed at the request of the German Defense Minister. Dipl.-Ing. H. Bestek concerned himself with the icing conditions, the types of ice formation, the effects of icing and the icing protection for the rotor blades [2].

Dipl.-Ing. H. Bestek participated in icing experiments using the BO 105 helicopter at the National Research Council in Ottawa, Canada. Dipl.-Ing. H. Bestek wrote a report on this icing experimental installation at the request of the German Defense Ministry [4].

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16. Abstract

The Institute of Flight Mechanics of the DFVLR is engaged in theoretical and experimental works on the solution of flight dynamic problems predominantly in the field of aeronautics. In the field of flight dynamics of aircraft, emphasis is laid on the project of a variable stability aircraft using the HFB 320-S1 research aircraft. Thus important flight test data may be obtained for current research activities supporting at the same time the improvement of methods to predetermine aircraft performance and handling qualities. In the recently added field of rotorcraft it is also the aim to make agree the results obtained from experiments with the theory. Further, emphasis is laid on investigations of rescue and recovery systems. Drop tests, model tests and theoretical investigations run side by side to approach the solutions of the numerous problems (such as function, dynamic behavior, strength). Important is the development of test vehicles and procedures. Finally, system analyses and system evaluations are performed with probabilistic and operations research methods in cooperation with other institutes.

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